Data acquisition and processing system for small hydro power plants

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Abstract

Contrary to large hydro power plants, small hydro power plants often operate without crew and with little or no instrumentation. This allows for increased probability for increased vibrations, increased wear, decreased availability, life span decrease etc. A data acquisition and processing system was built, that enables relatively easy installation and analysis for periodic checks and checks after revisions and upgrades. It consists of sensing, data acquisition and data processing parts. Sensing part enables installations of a wide range of sensors. The data acquisition part enables logging of average values, data streaming to disk and pre/post trigger acquisition. Data analysis part enables online and offline analysis. An example of measurements on small hydro power plant is presented.

1 Introduction

Slovenian company SENG (Soške elektrarne Nova Gorica, Soča river power plants Nova Gorica) is owner of 6 HPP (Hydro Power Plants) larger than 10 MW (one of them pumped storage) and 22 HPP smaller than 10 MW. All HPPs are located in the western part of Slovenia. SENG was established in 1947 and celebrated its 67th anniversary in 2014. Between 1965 and 1990, it pursued two activities: electricity production by HPPs and electricity transmission. Upon establishment, SENG took over from SADE, an Italian company, ten HPPs with a total installed capacity of 52 MW. Today, total installed capacity of HPPs owned by SENG amounts to 157 MW plus an additional 180 MW from one pumped storage HPP.

During commissioning of the HPP, standards set the procedure of performance testing. Besides acceptance test for rating, one of the most important tests of HPP are load rejection tests [SIST EN 60041:2001, 2001]. Although small HPP Hubelj was commissioned several decades ago, operator decided to regularly perform selected acceptance tests to check for the small HPP performance. For such testing, we have designed and built the data acquisition and processing system. The system is designed for repeated yearly measurements on the wide range of small HPPs with as little as possible work required measurement equipment installation.

In the following we will present the data acquisition and processing system information. We will present several modes of operation and capabilities for adaptation to various different small HPP. We will present a single measurements example of operation of the turbine pressure relief valve. Measurements were performed at small HPP Hubelj.

2 Measurements

In this section we will introduce the small HPP Hubelj, the purpose of measurements and review design of data acquisition and processing system.

2.1 Description of small HPP Hubelj

Small HPP Hubelj is an old power plant located in Ajdovščina, Slovenija. The HPP Hubelj operation start was in 1931. Much of the lifetime small HPP Hubelj operates without refurbishment. In year 1999 new runners and control equipment were installed and some mechanical components refurbished. Small HPP Hubelj uses water from stream Hubelj with head 110 m. The water Average discharge of the Hubelj stream is 2.80 m^3/s and the total rated discharge of the small HPP Hubelj is 2.70 m^3/s. Installed power is 2.1 MW with annual production 10,000 MWh. Installed are two Francis turbines, a larger one with 1.2 MW and a smaller one with 900 kW. Both turbines rotational speed is 1000 /min. Small HPP Hubelj machine room is shown in Fig. 1.

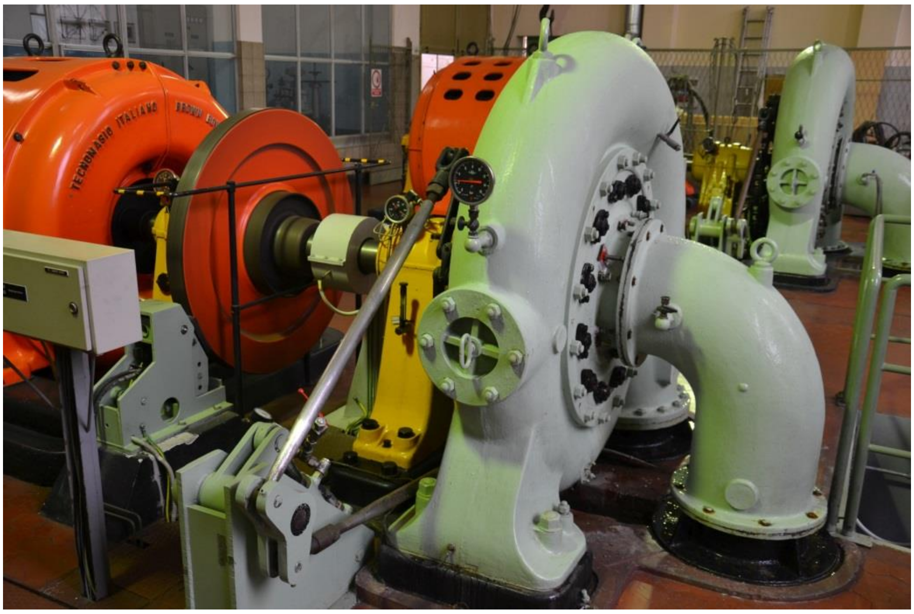

Fig. 1 Small HPP Hubelj machine room. Measurements were performed on the smaller turbine in the back of the machine room (P = 900 kW).

2.2 Pressure relief valve under test

Few years ago operators have experienced problems with a pressure relief valve on the smaller turbine (900 kW). The pressure relief valve is shown in Fig. 2. The pressure relief valve was refurbished and decision was made to make regular annual tests of pressure relief valve operation. Small HPP Hubelj is to a certain extent unique regarding installation and operation of pressure relief valve. Each of both turbines has a pressure relief valve installed in front of the ball valve just before the turbine. The purpose of the pressure relief valve installation is to alleviate pressure fluctuation and water in the penstock during turbine load rejection. During turbine load rejection, the pressure relief valve opens immediately with closing of the wicked gate and allows water from the penstock to flow directly into the tailrace channel. This was made possible during the turbine design with the horizontal installation of the shaft and short draft tube.

Pressure relief valve is in operation also during changes of the operational point of the turbine. Large changes of the wicket gate opening result in minor and short opening of the pressure relief valve. In such a way the pressure relief valve acts also as turbine control equipment.

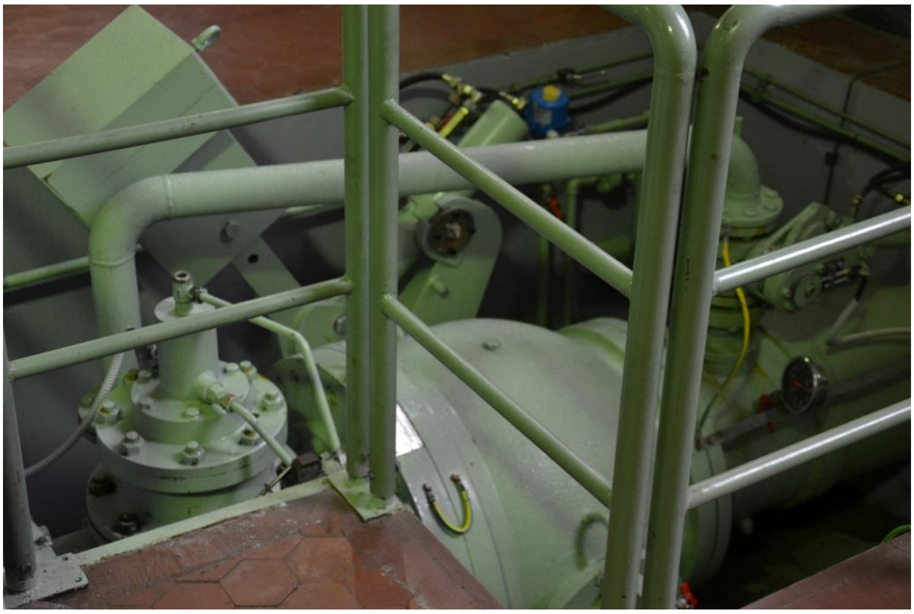

Fig. 2 Pressure relief valve (left) and ball valve (right) are located just in front of a turbine. Water flows from left to right.

The pressure relief valve control is achieved by two plates of different sizes. Smaller plate is located above, while larger plate is located in the bottom of the penstock. Thus, sudden increase of the pressure in the penstock creates a large force in the downwards direction and opens the pressure relief valve. The pressure relief valve thus does not require any external hydraulic, pneumatic or electric power for actuation.

The top of the pressure relief valve is connected to both plates, entire assembly is allowed to move 5 cm down when pressure relief valve is in operation. During measurements a wire displacement sensor was thus connected to the top of the pressure relief valve.

2.3 Data acquisition and processing software

The acquisition and processing software and hardware were designed to enable regular yearly checks of all SENG 22 small HPPs. The following data acquisition and processing procedures are possible:

- on line data fast acquisition and analysis (filtering, frequency analysis),
- off line data analysis (filtering, frequency analysis),
- connection to Siemens PLC controls, which are available on all 22 small HPPs for data exchange of variables, already measured on small HPPs (depends on the small HPP, but usually: flow rate, operational point, head, electric power etc.),
- logging of average/RMS/S_{max} values of measured variables for extended periods of time,
- logging of estimators for measured variables (average, RMS, standard deviation, S_{max}, peak-peak, max, min, crest factor),
- fast pre-trigger, post-trigger or combined pre/post-trigger fast data acquisition for transient analysis,
- saving of all measured variables on disk and
- loading and saving of all parameters on software startup and shutdown.

The software is written in National Instruments Labview programming environment. Hardware includes several National Instruments DAQmx analog input modules cDAQ for data acquisition and the power supplies and amplifiers for the following sensors:

- vibration sensors,
- wire displacement sensors,
- fast shaft displacement sensors (not used for this experiment),
- rotational frequency sensors (not used for this experiment) and
- pressure sensors.

In general, every sensor with voltage, frequency or current output can be used with the acquisition and processing software and hardware. Fig. 3 shows a sample of a program control tab of the user interface. Fig. 4 shows a sample of spectral analysis tab.

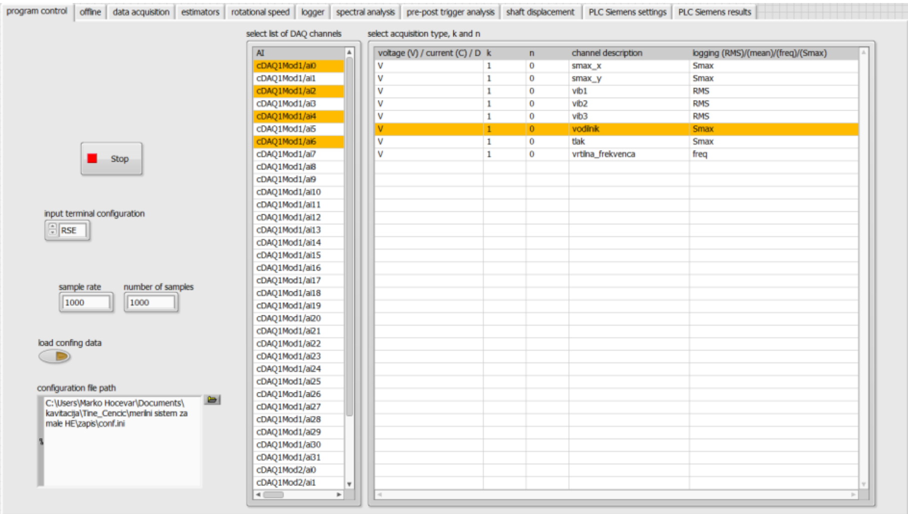

Fig. 3 In the program control tab user has to select the channels for data acquisition, k and n for physical units etc.

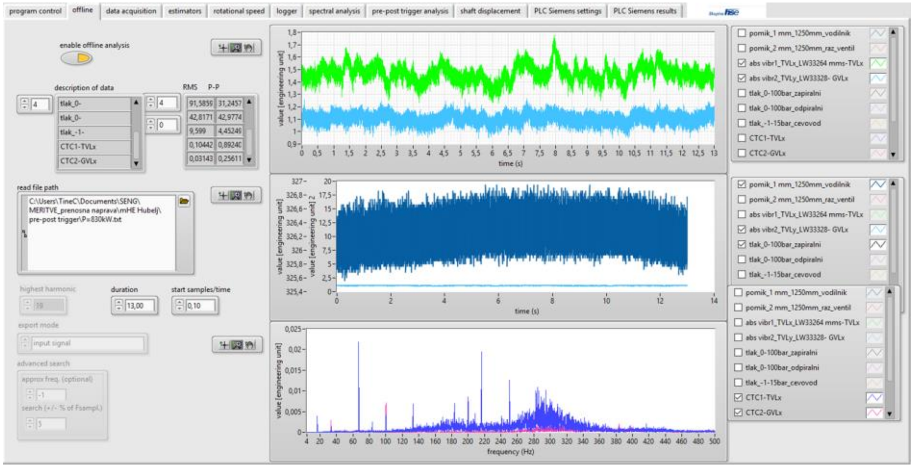

Fig. 4 The offline and spectral analysis tabs enable offline and online spectral analysis of selected channels. Rapid evaluation of bearings vibrations is possible.

2.4 Measurement variables

Load rejection test (from 75% of turbine power to full stop) was performed on 4.3.2016. The following variables were measured:

- absolute vibrations of both turbine and generator bearings, measured with absolute vibrations sensor type IMI 640B01, frequency range 3 - 1000 Hz, measurement range 0 - 25 mm/s, current output
- acceleration of both turbine and generator bearings, measured with accelerometers CTC tip AC240-1D, frequency range 0,6 - 25 kHz, sensitivity 100 mV/g, PS1002 power supply, voltage output
- pressure in the penstock (range 0 - 15 bar) and pressure in the hydraulic system (range 0 - 100 bar) for opening/closing of wicket gate pressure sensors ADZ Nagano SML - 10, measurement range 0 - 100 bar and 0 -15 bar, current output
- wicket gate position (guide vane ring) and pressure relief valve control system position, wire displacement sensor Kübler D8.3A1.0125.A221.0000, measurement range 0 - 1250 mm, voltage output

Connection to Siemens PLC control system was not required and therefore not used in this experiment. For measurements data acquisition modules NI 9205, NI 9203 (both with voltage inputs) and NI 9203 (current inputs) were used. All three data acquisition modules were inserted in the same cDAQ chassis embedded in the data acquisition and processing system

Results

Results of measurements of load rejection test at 75 % are shown in Figs. 5 and 6. After the load rejection test was initiated, the wicked gate has closed to a full turbine stop position in about 2 s. Pressure in penstock has increased by 1 bar. The pressure relief valve opened by 80 % in the same time period of closing of the wicked gate. Later, pressure relief valve returned to normal operation in much longer time period around 30 - 40 s.

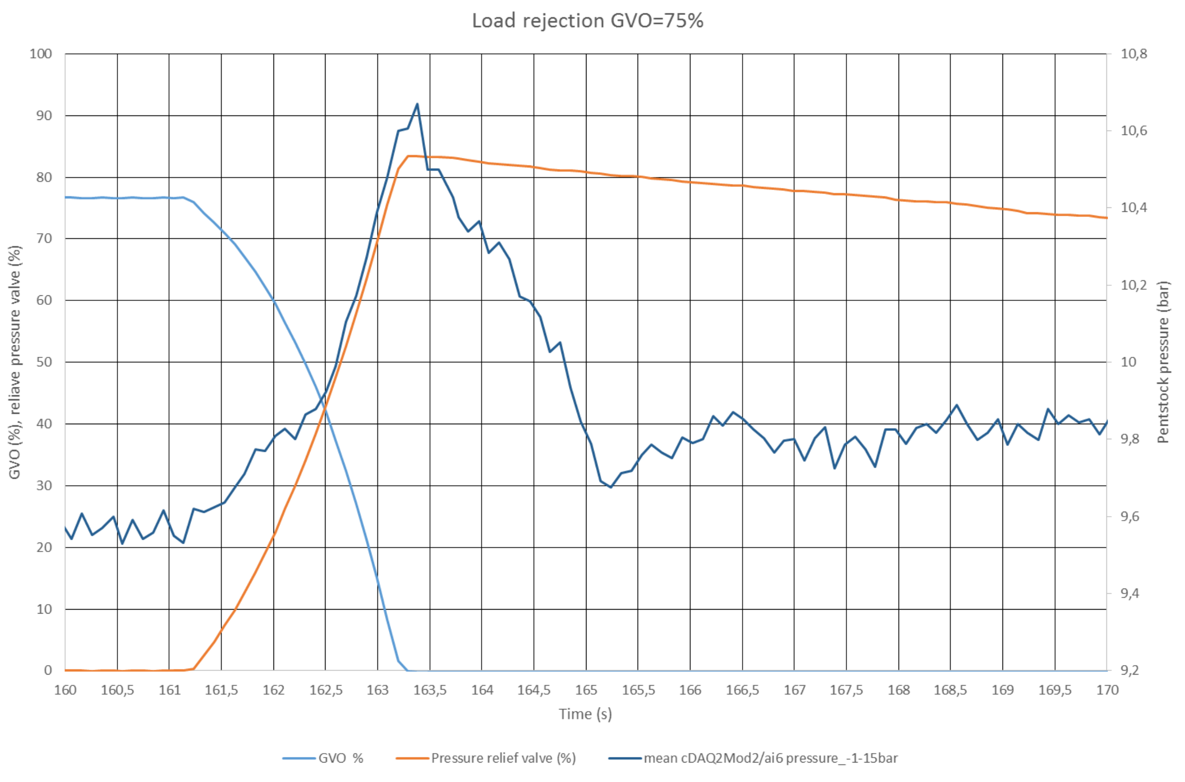

Fig. 5 Load rejection test at 75 %. Shown are pressure relief opening (%), wicked gate opening (GVO, in %) and pressure in the penstock (bar).

Fig. 6 shows, that even at small changes in power, which were initiated by small changes in wicket gate opening at around time *t* = 80 s, pressure in the penstock fluctuated. As a result of pressure fluctuations, vibrations levels on both turbine and generator bearing increased.

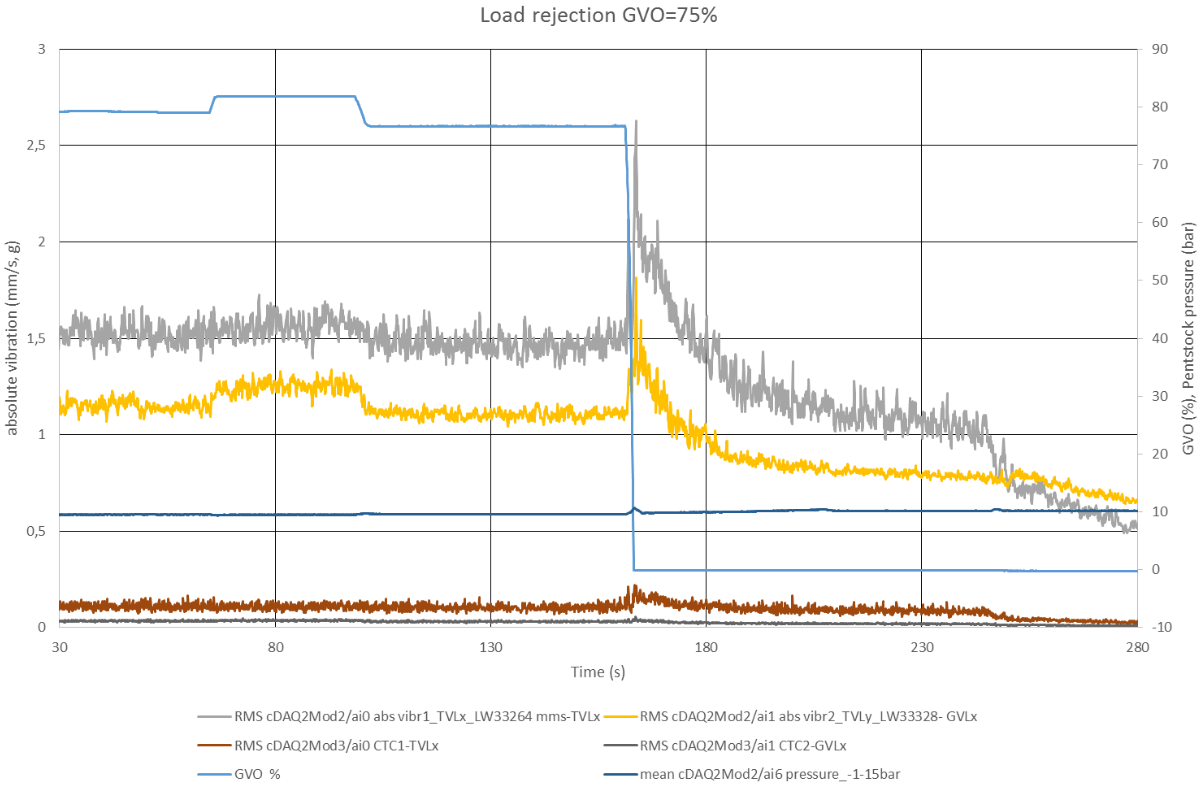

Fig. 6 Load rejection test at 75 %. Shown are wicket gate opening (GVO) and vibrations of turbine bearings (grey, purple yellow: turbine bearing - TVL and purple: generator bearing - GVL).

Analysis of guide bearing vibrations was also performed. During load rejection tests, vibrations increased but remained at acceptable levels. Also during normal operation, vibrations were low, they were evaluated by international standard [ISO 10816-1:1995, 1995]. The highest RMS measured value of vibrations of both turbine and generator bearings was during this experiment 1.47 mm/s. This is well below the allowed limit for the turbine machinery of this size [ISO 10816-1:1995, 1995].

Frequency spectrum of bearing vibrations shows low peak at the rotational speed of the turbine (16.667 Hz) showing that the entire turbine is well balanced.

Conclusions

Data acquisition and processing system for small hydro power plants was built and tested. The test was performed on the pressure relief valve of the small HPP Hubelj as a regular yearly check of mechanical equipment.

The data acquisition and processing system for small hydro power plants enabled reasonably fast installation and reliable measurements. The pressure relief valve operation has proved faultless. During load rejection test at 75 % the pressure relief valve opened by 80 % within the same 2 s period of closing the wicked gate. The pressure relief valve later started to close slowly.

Literature

SIST EN 60041:2001, Field acceptance tests to determine the hydraulic performance of hydraulic turbines, storage pumps and pump-turbines.

ISO 10816-1:1995 Mechanical vibration - Evaluation of machine vibration by measurements on non-rotating parts - Part 1: General guidelines.

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